Orographic Impacts on Liquid and Ice-Phase Precipitation Processes during OLYMPEX

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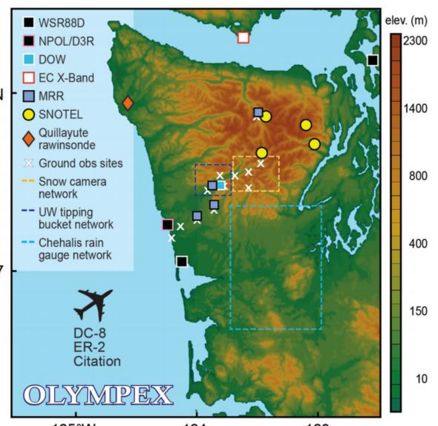
Introduction

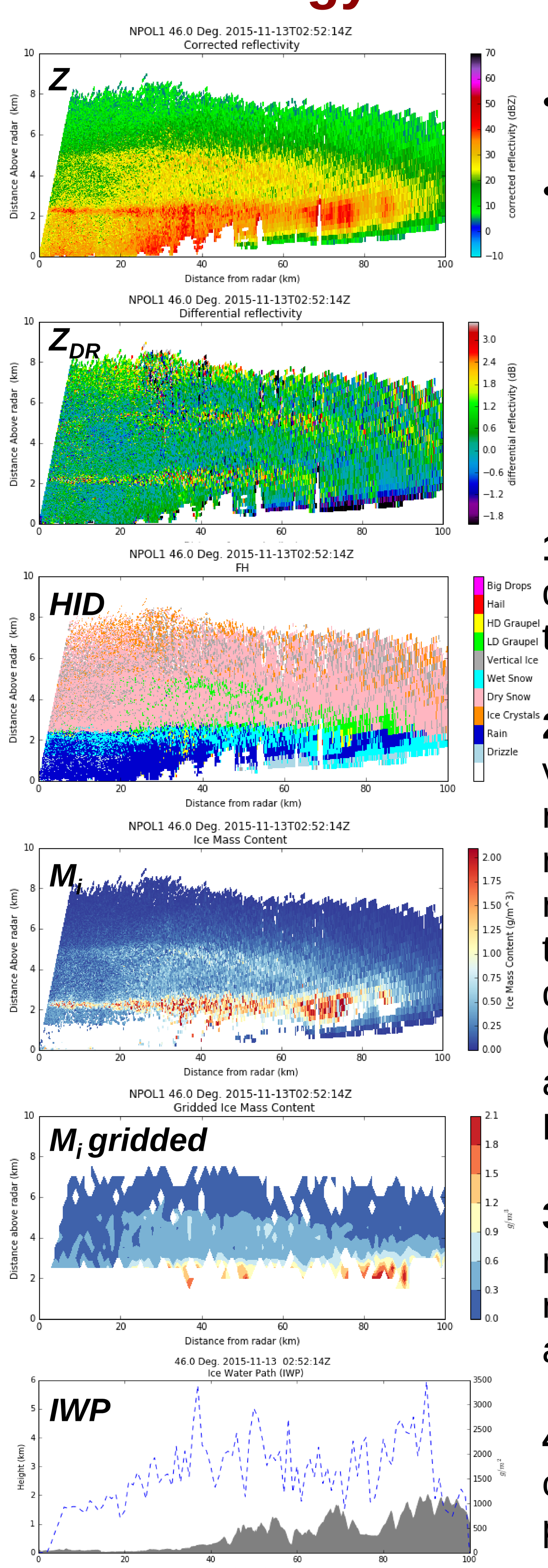
- NASA Global Precipitation Measurement (GPM) mission Olympic Mountain Experiment (OLYMPEX) winter of 2015-16
- Ground and airborne in situ and remote sensing measurements
- NASA S-band dual-pol radar (NPOL) used to analyze evolution of hydrometeor profiles as precipitation moved from the ocean and over mountainous terrain



Elevation and instrument location in the OLYMPEX domain in northwestern Washington

GPM radiometer-based precipitation retrieval algorithms over land rely strongly on ice-scattering signals. Hence, we use NPOL to evaluate the relative contributions of ice and liquid-phase orographic precipitation processes in the vertical column to the precipitation estimated at the surface. Attention is focused on the precipitation ice and liquid water paths (IWP, LWP, respectively).

Methodology



Calculating water paths with an RHI

- RHI scans observe vertical profile of hydrometeors
- IWP and LWP defined as the integration of ice and liquid water content (*IWC, LWC*)

$$\mathrm{IWP} = \int_{h_{\mathrm{base}}}^{h_{\mathrm{top}}} \mathrm{IWC}\, dh.$$

1. Use hydrometeor ID to discriminate between ice types and liquid

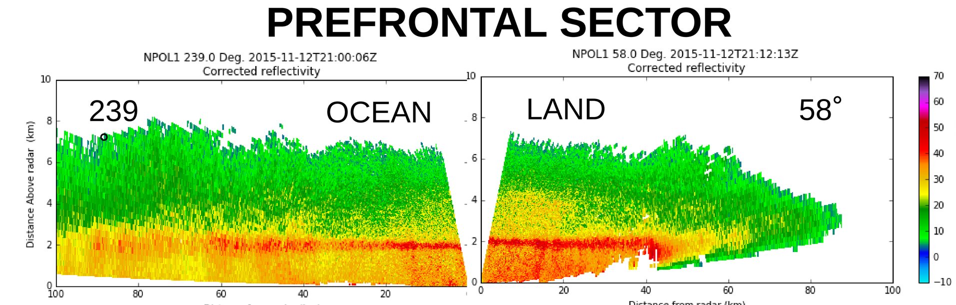
2. Calculate mass content values for ice and liquid ($M_{i,w}$, respectively) by relating reflectivity (Z) and differential reflectivity (Z_{DR}) to $M_{i,w}$ through relationships derived specifically from OLYMPEX (ice: Heymsfield et al. 2017*; liquid: 2D Video Disdrometer data)

3. Grid the newly calculated mass content variables with resolution 1000 m x 500 m (x- and z-direction)

4. Integrate gridded mass content values to acquire path

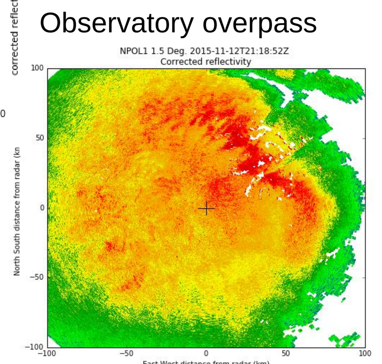
12-13 November 2015

PREFRONTAL SECTOR

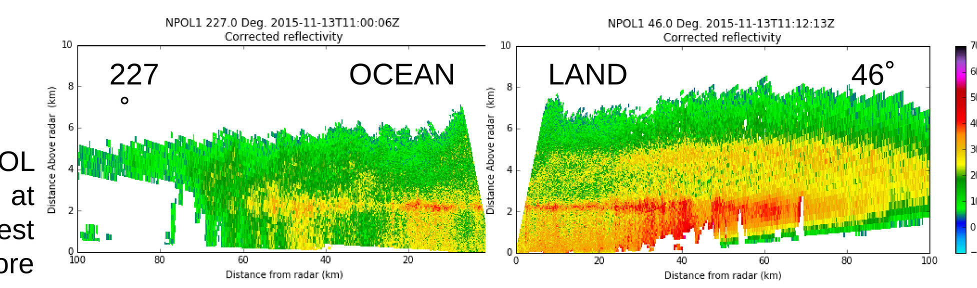


- Southerly, SSW flow
- GPM overpass at 21:15:53 UTC

Below: PPI of NPOL reflectivity (Z) at 21:18:52 UTC. Nearest time to GPM Core Observatory overpass



WARM SECTOR

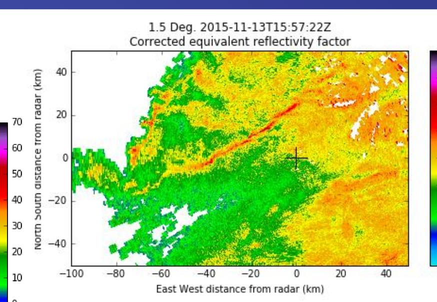


- Strong SW flow
- Atmospheric river

IWP and LWP values normalized with respect to changing elevation, dz (g m^{-2} m^{-1})

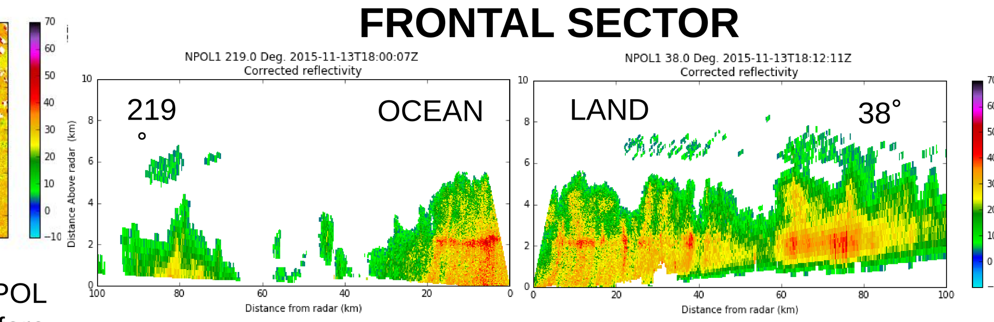
IWP
dz = echo top height - elevation

LWP
dz = melting level - elevation



Above: PPI of NPOL reflectivity (Z) during before passage of NCFR at 15:5722 UTC

FRONTAL SECTOR

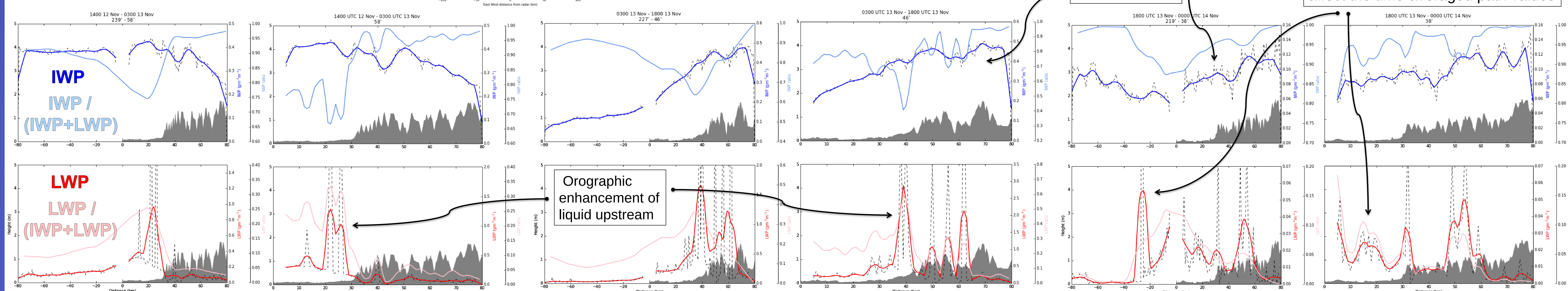


- Weakened surface flow, surface winds veering with time
- Narrow cold-frontal rainband

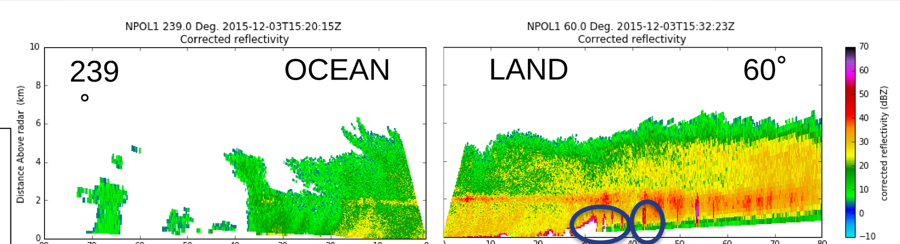
Enhanced contribution of ice over terrain

Convective elements and changing surface flow (speed and direction) affect the time-averaged path values

Orographic enhancement of liquid upstream

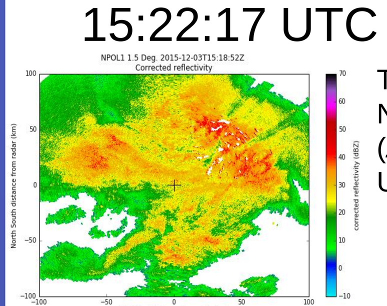


3 December 2015

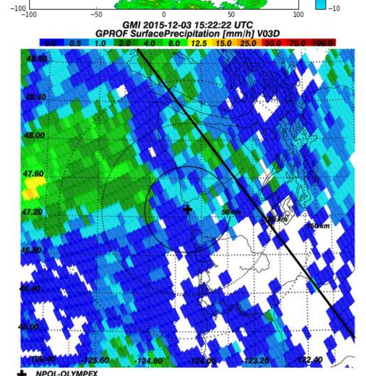


- Strong southerly flow
- GPM overpass at 15:22:17 UTC

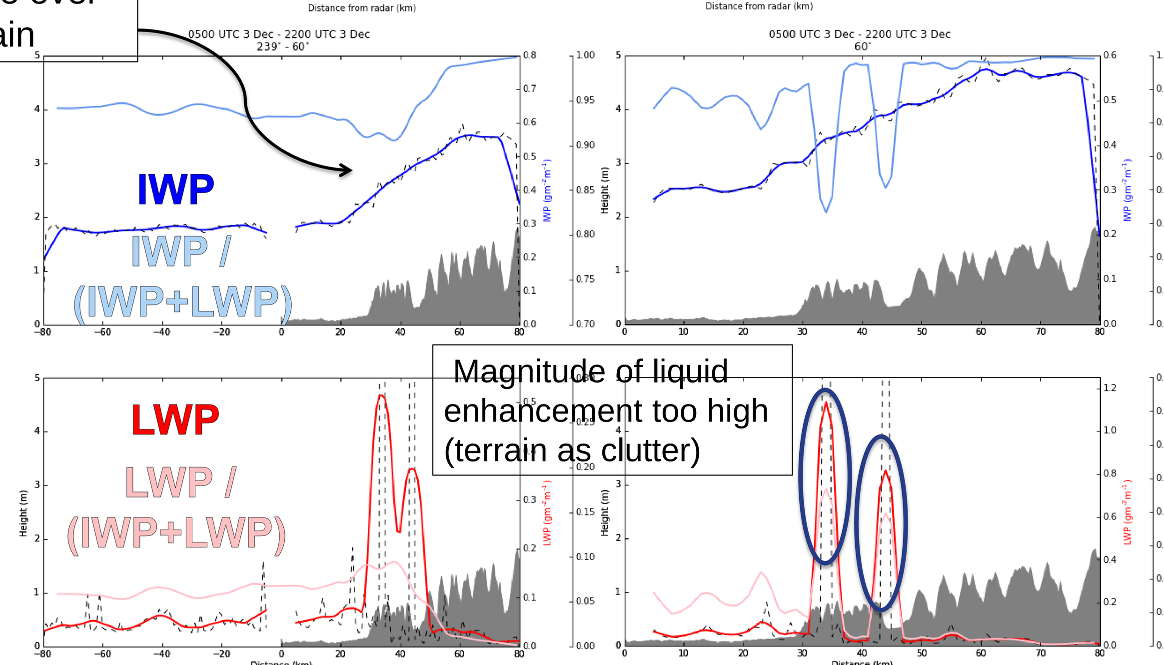
Enhanced contribution of ice over terrain



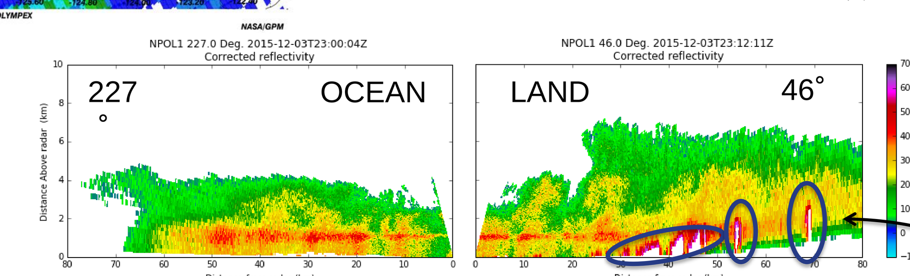
Top left: PPI of NPOL reflectivity (Z) at 15:18:52 UTC



Bottom left: GPROF surface precipitation (mmhr^{-1}) during GPM Core Observatory overpass at 15:22:22 UTC

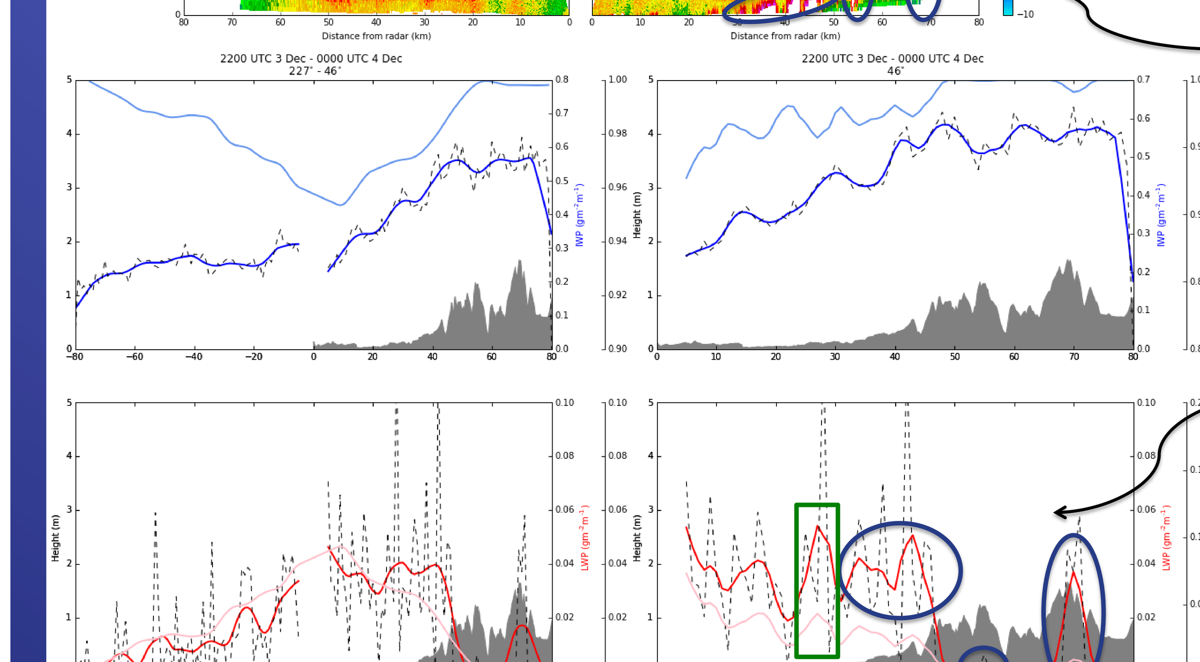


Magnitude of liquid enhancement too high (terrain as clutter)

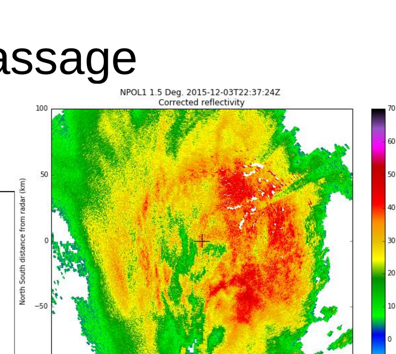


- Southerly flow transitioning to westerly
- Weak frontal passage

False liquid enhancement signal attributed to clutter (mountains) contaminating radar signal



Real liquid enhancement signal between **20-30 km**



Above: PPI of NPOL reflectivity (Z) at 22:37:24 UTC

Southerly flow is parallel to slopes sampled by NPOL, much smaller magnitude of liquid enhancement is seen (compare to 12-13 November)

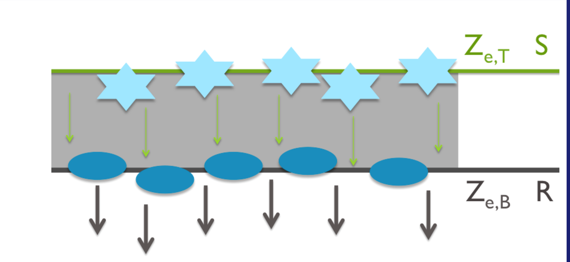
Conclusions

- Persistent trends in ice and liquid water path due to the orographic enhancement of ice and liquid through:
  - Collision-coalescence process
  - Seeder-feeder mechanism

  (enhanced ice process leads to more and larger snow melting and feeding into collision-coalescence below)
- Low-level flow important to the trends observed, for GPM algorithms
  - Use of **cyclone sectors** could be subjective
  - Objective metric such as **Froude number, Rossby number, Rossby radius of deformation**, and other parameters related to flow and stability can be calculated in models, incorporated into algorithms

Ongoing Work

- Complete analysis on primary cases with GPM overpass events
- Evaluate application of stability, upstream flow parameters and classifying cases by regimes based on these parameters
- Analysis of supplementary cases (smaller rainfall events, no overpass)
- Comparison of NPOL to GPM data (radiometer, radar)
- **Limitations**
  - Contamination of NPOL data by mountains
  - HID uncertainty, especially in ice (melting layer)



In order to approximate liquid contribution from the melting layer, will use mass-flux conservation assumption. If mass flux is approximately constant through the melting layer, rainfall rate, *R*, just below the melting layer will equal snowfall rate, *S*, just above melting layer.

Acknowledgments

We acknowledge the NASA GPM Program (Dr. Gail Skofronick-Jackson, GPM Project Scientist) for supporting this research. We acknowledge Dr. Stephanie Wingo for discussions related to this work.

*Heysmfield, A.J., A. Bansemer, N.B. Wood, G. Liu, S. Tanelli, S. Ousmane, M. Poellot, and C. Liu, 2017: Development of triple wavelength snowfall and rainfall rate relationships to radar reflectivity from collocated aircraft in situ and overflying radar data and from global satellite radar measurements. *J. Appl. Meteor. Climatol.*, accepted for publication.